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DISCUSSION OF SEWAGE RECLAMATION BY SPREADING BASIN INFILTRATION SPREADING

(*Published in September, 1951*)

By R. B. Krone, J. F. Thomas, and Harvey F. Ludwig; A M Rawn and F. R. Bowerman; and Ralph Stone and William F. Garber

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Technical Division	*Proceedings-Separate Number*
Air Transport	42, 43, 48, 52, 60, 93, 94, 95, 100, 103, 104, 108, 121, 130 (Discussion: D-XXVIII, D-7, D-16, D-18, D-23, D-43, D-75)
City Planning	58, 60, 62, 64, 93, 94, 99, 101, 104, 105, 115, 131, 138 (Discussion: D-16, D-23, D-43, D-60, D-62, D-65, D-86)
Construction	43, 50, 55, 71, 92, 94, 103, 108, 109, 113, 117, 121, 126, 130, 132, 133, 136, 137 (Discussion: D-3, D-8, D-17, D-23, D-36, D-40, D-71, D-75, D-92)
Engineering Mechanics	122, 124, 125, 126, 127, 128, 129, 134, 135, 136, 139, 141 (Discussion: D-24, D-33, D-34, D-49, D-54, D-61, D-96, D-100)
Highway	43, 44, 48, 58, 70, 100, 105, 108, 113, 120, 121, 130, 137, 138 (Discussion: D-XXVIII, D-23, D-60, D-75)
Hydraulics	50, 55, 56, 57, 70, 71, 78, 79, 80, 83, 86, 92, 96, 106, 107, 110, 111, 112, 113, 116, 120, 123, 130, 134, 135, 139, 141 (Discussion: D-70, D-71, D-76, D-78, D-79, D-86, D-92, D-96)
Irrigation and Drainage	97, 98, 99, 102, 106, 109, 110, 111, 112, 114, 117, 118, 120, 129, 130, 133, 134, 135, 138, 139, 140, 141 (Discussion: D-XXIII, D-3, D-7, D-11, D-17, D-19, D-25-K, D-29, D-30, D-38, D-40, D-44, D-47, D-57, D-70, D-71, D-76, D-78, D-80, D-86, D-87, D-92, D-96)
Power	48, 55, 56, 69, 71, 88, 96, 103, 106, 109, 110, 117, 118, 120, 129, 130, 133, 134, 135, 139, 141 (Discussion: D-XXIII, D-2, D-3, D-7, D-38, D-40, D-44, D-70, D-71, D-76, D-78, D-79, D-86, D-92, D-96)
Sanitary Engineering	55, 56, 87, 91, 96, 106, 111, 118, 130, 133, 134, 135, 139, 141 (Discussion: D-29, D-37, D-56, D-60, D-70, D-76, D-79, D-80, D-84, D-86, D-87, D-92, D-96)
Soil Mechanics and Foundations	43, 44, 48, 94, 102, 103, 106, 108, 109, 115, 130 (Discussion: D-4, D-XXVIII, D-7, D-43, D-44, D-56, D-75 D-86)
Structural	42, 49, 51, 53, 54, 59, 61, 66, 89, 100, 103, 109, 113, 116, 117, 119, 121, 122, 123, 124, 125, 126, 127, 128, 129, 132, 133, 136, 137 (Discussion: D-51, D-53, D-54, D-59, D-61, D-66, D-72, D-100)
Surveying and Mapping	50, 52, 55, 60, 63, 65, 68, 121, 138 (Discussion: D-60, D-65)
Waterways	41, 44, 45, 50, 56, 57, 70, 71, 96, 107, 112, 113, 115, 120, 123, 130, 135 (Discussion: D-8, D-9, D-19, D-27, D-28, D-56, D-70, D-71, D-78, D-79, D-80)

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DISCUSSION

R. B. KRONE,[12] J. F. THOMAS,[13] AND HARVEY F. LUDWIG,[14] A. M. ASCE. —The method of sampling described in this paper has also been used by the writers in a field testing program[15] at Lodi, Calif., in which collection pans were placed at varying depths in the soil in shafts dug from a well placed at the center of each test plot. Extensive use of the pan method showed it to have the following disadvantages:

(1) It is difficult to place the pans without disturbing the overlying soil, and even more difficult to secure a good bond between the pan and the overlying soil;
(2) The method fails when the percolating water is under tension (less than the atmospheric pressure), a condition often found, especially in stratified soils;
(3) The flow path and perhaps the characteristics of the percolating water are seriously altered; and
(4) The size of the pans, if large enough to collect significant samples, limits the number that may be used, and hence makes it difficult to collect samples from enough locations to assure representative results.

An improved and more convenient sampling laboratory method[16] involves the use of a porous tube or "probe," inserted in the soil at the desired sampling depth, to which negative pressures or tensions are applied. The porous tube is comparable in size and porosity to a coarse bacteriological filter. It extracts water from the soil by forming a hydrodynamic sink. The configuration of the flow and the pressures around the probe are similar to those existing around the perforated zone of a well into which underground water is flowing. However, the magnitude of the tension applied to the probe is so slight that the volume or region of soil affected is very small, extending only about 10 cm from the probe for applied probe tensions of about 100 cm of water. Thus the disturbance caused by the sampling scarcely affects the general pattern of the flow of water through the soil.

The proper tension to be applied to the probe depends upon the soil permeability, the frictional resistance of the probe material and of the connecting tube, and the initial soil solution pressure. The necessary probe tension is readily applied by means of a hanging water column. With a probe of proper dimensions and porosity, the feasible yield per probe is about 20 ml per hr.

NOTE.—This paper by Ralph Stone and William F. Garber was published in September, 1951, as *Proceedings-Separate No. 87*. The numbering of footnotes, tables, and equations in this Separate are a continuation of the consecutive numbering used in the original paper.

[12] Soil Scientist, San. Eng. Research Project, Univ. of California Field Station, Richmond, Calif.

[13] Research Chemist, San. Eng. Research Project, Univ. of California Field Station, Richmond, Calif.

[14] Associate Prof. of San. Eng., Univ. of California, Berkeley, Calif.

[15] "Reclamation of Sewage Water," by A. E. Greenberg and H. B. Gotaas, *American Journal of Public Health*, Vol. 42, April, 1952, p. 401.

[16] "Porous Tube Device for Sampling Soil Solutions During Water Spreading Operations," by R. Krone, H. F. Ludwig, and J. F. Thomas, *Soil Science* (publication pending).

A M Rawn,[17] M. ASCE, and F. R. Bowerman,[18] J. M. ASCE.—The case for reclamation of sewage effluents by recharge of ground-water gains added support from the excellent performance data on operating percolation ponds presented in this paper. Reclaimed sewage effluent has been directly re-used for industrial and agricultural purposes in many places and on many occasions, and the records of such re-use abound in the literature.[11,19,20,21] The Stone-Garber paper, however, presents a practical method whereby sewage effluent percolated into the ground may be rendered wholly acceptable for any and all uses to which normal ground waters may be placed.

Direct re-use of sewage effluents is highly restricted, but the infiltration of such sewage effluent through the soil and into ground waters permits unrestricted use of such waters upon subsequent pumping. A preliminary report presents part of these data on reclamation by spreading-basin infiltration.[11] The authors have re-analyzed and amplified this information and have shown more precisely what results were obtainaed.

It is of particular interest to note the widely differing character of the soil at the two spreading areas under consideration. At Whittier, Calif., the soil was tight; cursory examination would suggest that it was not appropriate for recharge purposes. In referring to the Azusa basins (Calif.), the term, soil, was almost a misnomer in that once the thin surface layer was pushed aside, the material remaining was a very coarse mixture of sand and gravel—a highly permeable medium. Consideration of the excellent performance recorded at both sites increases one's confidence in the general thesis of sewage reclamation by spreading basin infiltration.

Some significant questions are posed by this paper. First: What effect does long-term spreading have upon the underground geological formations that receive the effluents? It is logical to anticipate that the structural and chemical nature of the soil will be changed by the pickup or loss of inorganic constituents which may be deposited in the soil or leached from it into the percolating water. An operation extending over several years might yield results somewhat different from those observed during the short period of the test runs. The chemical or physical changes occurring in the soil can be observed by suitable testing, although long periods of time might elapse before such changes appear. The Azusa basins have been operated as sewage effluent percolation ponds since 1943 and it would be expected that any changes occurring underground would already have taken place. However, the alluvial deposits at Azusa may not be representative of other conditions as they are stream-washed and, consequently, contain little organic or other chemical components.

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[17] Chf. Engr. and Gen. Mgr., County Sanitation Dists. of Los Angeles County, Calif.

[18] San. Engr., County Sanitation Dists. of Los Angeles County, Calif.

[11] "Report Upon the Reclamation of Water from Sewage and Industrial Wastes in Los Angeles County, California," by C. E. Arnold, H. E. Hedger, and A M Rawn, Los Angeles County Sanitation Dists., Los Angeles, Calif., April, 1949.

[19] "Industrial Uses of Reclaimed Sewage Effluents," by N. T. Veatch, *Sewage Works Journal*, Vol. XX, January, 1948, pp. 3–11.

[20] "Agricultural Uses of Reclaimed Sewage Effluent," by L. V. Wilcox, *ibid*, pp. 24–33.

[21] "The Utilization of Sewage Water for Agriculture," by A M Rawn, *Proceedings*, 18th International Cong. of Agri., Dresden, 1938.

A second question: What effect does the continual discharge of sewage effluents through a percolation pond have on the receiving underground waters? The chemical content of the underground waters immediately underlying an infiltration basin must reflect the chemical nature of the sewage effluent introduced above it. Although the authors clearly indicate that bacteria and organic matter are filtered out within a few feet, the chemical nature of the effluent is little changed, except possibly through exchange with the soil. An examination of ground waters surrounding existing percolation ponds should indicate the extent to which chemicals are added to the underground waters.

In an investigation, it is seldom possible to study all phases of a problem, and it is not with the thought of criticism, but merely as a suggestion, that these particular questions are presented. The transfer of chemical constituents between the soil and the water will exert some effect on the final condition of the effluent as it reaches the underground waters. However, this will probably prove to be of secondary importance, and it is doubted if the over-all picture will be greatly affected. The importance of reclaiming, for re-use, a steady and reliable source of water, suitable for return to the underground aquifers—particularly in semi-arid areas such as Southern California—makes it necessary that all aspects of this problem be resolved as quickly as possible.

Ralph Stone,[22] A. M. ASCE, and William F. Garber[23].—The investigators (Messrs. Krone, Thomas, and Ludwig) at the University of California have reviewed the effectiveness of subsurface sampling of percolating waters with collection pans in contrast to the use of a porous probe, which is essentially a tube with a porous ceramic membrane tip, operated with negative heads induced by a vacuum pump or a hanging column of water. It is true that it may be difficult to place collection pans without disturbing the overlying soil and even more difficult to secure a good bond between the pan and the overlying soil. However, with the full comprehension of the factors involved in achieving continuity between the collection pan media and the overlying soils, an effective percolation pattern was achieved in fact, both at the Azusa and Whittier test basins since satisfactory large volumes of percolated waters were collected at a rate varying between 1 gal and 0.1 oz per 10 min of sampling period, depending on the concurrent velocities of the surface percolation. The University of Southern California investigation of leaching from dumps[24] has successfully utilized a type of collection pan placed into undisturbed soils for their leaching studies. Similarly, the Lodi test conducted by the University of California (at Berkeley) employed collection pans for the sub-surface sampling device.

In the "Waste Water Reclamation and Utilization Project" (University of California at Los Angeles), the investigators are continuing to employ the same installation of collection pans described for the Azusa test site. After four years of utilization at the test basin site, these Azusa collection pans still operate

[22] San. Engr., Univ. of California, Los Angeles, Calif.

[23] Lab. Director, Hyperion Sewage Treatment Plant, Los Angeles, Calif.

[24] "Investigation of Leaching from Dumps," Dept. of Eng., San. Eng. Lab., Univ. of Southern California, Los Angeles, Calif., *Monthly Progress Reports Nos. 5 to 8*, July to October, 1951.

efficiently, as judged by the consistency of chemical and bacteriological data obtained from these sources. At both the Whittier and Azusa test basins, the collection pans were installed carefully by the physical removal of the surface material and then backfilled carefully to assure continuity between the liquid phase of the covering soils and that of the interior of the collection pans. With the passage of time, superior consolidation of this backfill has taken place at the Azusa installation thereby approaching the undisturbed soil condition. Still, there has not been a noticeable change in the quality of the samples collected.

Soil Moisture Tension.—Under conditions of high soil moisture tension, there is little movement of free capillary water through the soil. Soil moisture tension can be defined as the molecular attraction or "wetting" between the water molecules and the soil particle surfaces. Before appreciable gravity flow can take place in the soil interstices, these soil particle surfaces must be "wetted" and the capillary soil pores filled. This moisture demand is often called the field capacity of a soil. Only after the surface tension forces have filled the capillary pores can the smaller forces of gravity act to allow water to percolate in appreciable quantities through the open soil interstices. It is possible to measure, actually, the hydraulic gradient of the water in a soil by use of devices called "tensiometers." These tensiometers are similar to manometers except that they have a ceramic membrane top so that they record the direct positive pressures of the liquid phase at the surface of a soil column as well as the negative pressures resulting from surface tensions in the water covering the capillary pores and particle surfaces. Under conditions of evaporation or plant transpiration of the soil moisture, these tensiometers (located at different depths in the soil) actually can measure the hydraulic gradient in the liquid phase of the soil moving the moisture toward the top of the soil column. The negative surface tension of liquid phases, with percolation rates in the range of 0.2 ft per day, is -2 ft to -4 ft of water head, whereas the tensiometer readings, when evaporation and transpiration result in upward movement of the soil moisture, are as low as -5 ft to -10 ft of water head. Hence, it can be stated that, when the collection pan sampling method fails, little if any downward movement of recharge water into the underground aquifers occurs. The rate of flow of percolated water can be equated as follows:

$$V = K\,\Delta H \qquad (1)$$

in which the velocity of flow is V; the permeability coefficient is K; and the difference in hydraulic gradient between two points a and b is ΔH. Hence, if the rate of percolation or flow is measured and the hydraulic gradient between two points a and b in the soil column are determed through the use of tensiometers, then the permeability of the soil column (a–b) can be calculated.

$$K = \frac{\Delta H}{V} \qquad (2)$$

Porous Probe.—The porous tube or probe actually alters the hydraulic movement pattern of the percolated water by causing a hydrodynamic sink with negative hydraulic gradient in the liquid phase. Thus, capillary water

will move toward the porous probe operating under vacuum. The porous probe, therefore, withdraws the surface tension waters while the collection pan intercepts free water moving through the interstices as a result of the action of gravity.

The reason that the Berkeley investigators have not adopted the porous probe for field sampling is that a probe of proper dimensions and porosity will collect only a feasible "yield" per probe of 20 milliliter per hr. However, the collection pan, under conditions of high percolation, discharges much greater volumes of percolated effluent and, therefore, is much more convenient for field sampling. Finally, field samples collected for bacteriologic, B.O.D., turbidity, and possibly other analyses would be appreciably affected by filtration through the ceramic membrane. Therefore, such samples could not be obtained satisfactorily with a probe.

Rawn-Bowerman Discussion.—Messrs. Rawn and Bowerman have quite properly stated that considerable field experience has been obtained empirically about industrial and agricultural re-use of waste waters. Furthermore, the county sanitation districts cooperated in the performance of the Whittier and Azusa studies by making available the services of the laboratory and the laboratory personnel of the districts. A preliminary report covering a part of the data has been published.[11]

Performance of Intermittent Sand Filters.—It is well known that the effluent from intermittent sand filters and fine grain contact beds produce a clear, well nitrified, and stabilized effluent.[25] The spreading basins represent, in essence, natural filters that are generally of even a finer particle size than sand filters or fine-grain contact beds. Hence, it would be obvious that sewage spreading can be considered as a legitimate type of sewage treatment. Initially, a continuously operated spreading basin acts as an oxidation pond which reduces both the organic load and the pathogenic organisms content by (1) storage, (2) the activity of either aerobic or anaerobic biological action, and (3), of course, the filtration phenomenon which can also be considered both physical and biochemical action.

The Whittier and Azusa tests clearly indicate the following: (1) The remarkable effectiveness of such sewage filtration in stabilizing organic matter and removing pathogenic organisms, particularly under an aerobic environment, with a B.O.D. loading of from 40 lb to 100 lb per wetted acre; (2) the recharge percolation rate is largely controlled by the spreading-basin surface condition and the manner of spreading-basin operation; (3) the major effect of algae was that of providing additional oxygen during the warm daylight hours; (4) the importance of drying out the surface of spreading basins in order to redevelop high percolation rates; and (5) no mosquito or fly nuisances were noted at Azusa in the regularly operated old spreading basins. The old basins had evidently developed a balanced biological cycle wherein predatory insects and other organisms controlled the presence of mosquitoes, whereas the new test basins allowed the propagation of mosquito larvae.

[25] "Sewerage and Sewage Disposal," by L. Metcalf and H. P. Eddy, McGraw-Hill Book Co., Inc., New York, N. Y., p. 567.

Whittier.—The Whittier sandy loam soil maintained effective recharge rates averaging more than 1 ft of water per day for one week of continuous operation of the spreading basin. These initial Whittier and Azusa tests indicate the importance of maintaining fluid depths of more than 1 ft for effective filtration rates. At the 0.5-ft depths of spreading in these basins, the percolation rates were much less than when the normal 1-ft depth basin head was employed (Figs. 3 and 4). The Whittier well waters fed by the recharged sewage effluent were chemically and bacteriologically satisfactory to the adjacent farmers. No complaints by health or other authorities on water quality have ever been placed against these Whittier wells.

Anaerobic Disposal Operation.—The Whittier-Azusa tests quite clearly indicate that, under anaerobic environmental conditions, there can be considerable noxious odor in the spreading basins. In addition, with the anaerobic environment, the samples collected at various depths in the soil had reduced effluent quality when measured in terms of (1) high counts of MPN coliform, (2) presence of increased B.O.D., and (3) reduced spreading-basin percolation rates (see Fig. 4). Nevertheless, these studies indicated the fact that there was considerable treatment even under anaerobic environment of the spread effluent and that the B.O.D. and MPN counts for the spread sewage, after anaerobic percolation, were considerably reduced. As stated, the efficiency of the aerobic percolation is much higher, however.

Soil Influence.—The point has been raised about the type of soils satisfactory for percolation or recharge purposes. The controlling factor, as evidenced by the Whittier-Azusa tests, are that any soil is satisfactory which is permeable enough to allow a satisfactory entrance and percolation of water for effective recharge. In fact, the finer grained soils provide greater surface area and thereby insure more satisfactory biological and physical filtration. Of course, very fine clay soils of very low permeability would be practically impervious to the movement of percolating water and therefore, would be unsatisfactory for spreading basins.

The Effect of Long-Term Spreading on Soils.—Waste waters spread into the soil can be classified in their effect exactly as any other similar mineral type water. Waste waters can be employed feasibly for leaching alkali soils and, thereby, reclaiming such soils that would otherwise be uneconomical to reclaim with other water sources. Spreading basins have been used to recharge aquifers at Azusa since before 1940 and there has not been any noticable reduction in the capacity of soil to percolate the effluent. Since before 1927, numerous other farm locations including Pomona, Fresno, Bakersfield, and Ontario—in California—have been operating without noticeable deleterious effects on the receiving soil strata. Hence, the effect of infiltration of spread water on the underground geological formations can be summarized as follows: (1) The infiltrating sewage will leach out and drain alkalis present in the surface soil so that a continuous steady-state permeable condition prevails; (2) where a satisfactory percentage-sodium relation exists in the spread effluent, the clay and other colloids remain flocculated and allow maximum permeability (however, with a high-percentage-sodium, chemical deflocculation of the clay, colloids may appear which will reduce the permeability of the porous media);

(3) the organic material and organic growths in the soil under proper cycles of resting and desiccation will not interfere with percolation and, in fact, may assist in maintaining high percolation rates;[26] (4) fines—that is, small, inert particles introduced into the surface of the spreading basin—will reduce percola-

TABLE 4.—PERMISSIBLE LIMITS FOR DISSOLVED SOLIDS, BORON, CHLORIDE (IN PARTS PER MILLION) AND PERCENTAGE OF SODIUM

Factor	Class 1	Class 2	Class 3
	Excellent to good	Good to injurious	Injurious to unsuitable
Percentage of sodium[a]	< 60	60 to 75	> 75
Parts per million			
Total dissolved solids (D.O.)	<700	700 to 2,100	>2,100
Boron	> 0.5	0.5 to 2.0	> 2.0
Chloride	178	178 to 355	> 355

[a] $\frac{\text{Sodium} + 100}{\text{Calcium} + \text{magnesium} + \text{sodium} + \text{potassium}}$.

TABLE 5.—MINERAL PICKUP RESULTING FROM WATER SUPPLY UTILIZATION

Analysis[a]	City of Azusa[b]				City of Los Angeles[c]			
	Average potable water	Average percolated effluent[d]	Mineral pickup	Cycles of re-use[e]	Average potable water	Average hyper-ion effluent	Mineral pickup	Cycles of re-use[e]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Sodium, Na^+	9.6	53.0	43.4	...	45.2	200	154.8	...
Potassium, K^+	3.1	12.5	9.4	...	4.0	20	16.0	...
Calcium, Ca^{++}	54.4	51.2	0	...	31.2	92	60.8	...
Magnesium, Mg^{++}	14.4	15.5	0	...	7.2	21	13.8	...
Sodium (%)	11.8	40	28.2	three to five	51.8	60	8.2	one to eight
Chloride, Cl^-	11	44	32	five to eight	23	236	213	one to two
Boron, B	0.1	0.3	0.2	two to seven	0.43	0.42	0	many
Total solids[f]	260	432	172	three to six	262	769	507	one to three

[a] Units are parts per million except sodium (%) = $\frac{\text{sodium} \times 100}{\text{calcium} + \text{magnesium} + \text{sodium} + \text{potassium}}$.
[b] Primarily domestic utilization of water.
[c] Domestic, industrial waste, and salt brines introduced into sewage.
[d] Average percolated effluent at a depth of 7 ft.
[e] Refer Table 4 for "good to injurious" permissible limits of certain ions.
[f] Total dissolved solids.

tion rates, of course, but these can be removed by scarification of the basin surface; and (5) in the operation of cesspools and septic tanks, the Azusa and other spreading basins observed by the authors indicate that there is no unpredictable change in soil characteristics and that breakdown of the geological formations resulting from percolation of effluents is similar in nature to that of

[26] "Research in Water Spreading," by Dean C. Muckel, *Proceedings-Separate No. 111*, December, 1951, p. 9.

water infiltration providing that the recharged waters are comparable in mineral quality.

Chlorides.—The chloride analyses at the Whittier test plot indicate that the leaching of the soluble salts occurred in the top soil. This leaching should have stopped when the salts were completely washed out. The percolated effluents at the Azusa tests did not show evidence of either leaching or soil breakdown. These Azusa soils that have been percolated continuously for many years show no evidence of breakdown.

The Effect of the Sewage Effluents on the Irrigation of Plants.—The paper indicates that, even disregarding the dilution effect of underground aquifer waters from other sources, the reclaimed effluent still might be recycled two to five times before mineral pickup would be great enough to present a problem.

TABLE 6.—CHEMICAL ANALYSES OF WELL WATER IN THE AZUSA AREA[a]

Date	Well No.	$K \times 10^5$	Total solids	Hardness as $CaCO_3$	CO_3	HCO_3	Cl	SO_4	NO_3	Ca	Mg	Na+K
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Aug. 21-31	4217	43	...	...	14.05	0	0.52	1.22	0.23	3.44	0.99	0.99
Aug. 30-50	4236	...	352	328	212	0	12	34	Tr.	72	36	None
Aug. 30-50	4239A	...	490	464	216	0	32	120	5	120	40	None
Nov. 14-50	4248	...	330	207	216	0	16	21	Tr.	60	14	7
Nov. 8-50	4255C	...	210	178	144	0	12	169	None	60	7	None
Aug. 30-49	4257	...	414	393	224	0	44	148	30	80	47	3
Nov. 9-50	4259	pH6.9	360	331	216	0	12	98	10	88	27	None
Nov. 18-50	4267[b]	...	872	481	264	0	232	168	15	132	37	109
Feb. 28-50	4268	...	430	338	212	0	20	77	10	96	24	None
Nov. 9-50	4278	...	396	373	228	0	28	52	10	92	35	None
Nov. 8-51	4284B	pH6.4	...	...	216	0	16	67	...	...	...	...
Aug. 5-51	4285	...	420	390	208	0	8	86	None	84	44	None
Nov. 14-50	4286	...	250	111	128	0	8	34	Tr.	28	10	19
Aug. 30-51	4287A	...	492	458	252	0	28	213	40	136	29	4
Sept. 1-49	4287A	...	334	279	248	...	20	33	20	84	17	None
Aug. 21-31	4289	48.7	...	...	13.52	0	0.52	1.57	1.57	3.38	1.05	1.34

[a] Units are in parts per million except first and last lines which are grains per gallon. Except the data in the first line, these tests were observed at the laboratory of The Los Angeles County Flood Control District. The first line was reported by the Division of Water Resources, State of California. The boron content was less than 0.5 parts per million in each test reported. [b] Cyanamide plant.

Perhaps it would be well to review the mineral standards, developed at the Rubidoux Regional Salinity Laboratory, United States Department of Agriculture, that are generally accepted as fair criteria for irrigation water quality. Using the standards described in Table 4, the mineral analyses for the increment of mineral pickup of the Azusa and Los Angeles sewage over the potable water supplies are enumerated in Table 5. By reviewing these tables, it is evident that it is feasible to re-use these waste waters from one to five times before reaching mineral classifications that would be unsatisfactory for agricultural purposes. The Hyperion sewage treatment plant is introduced into this discussion because of the large (averaging 220,000,000+ gal per day) volume of water discharged into the ocean from the plant. Considerable quantities of industrial wastes and salt brines are introduced into the plant influent and, under a program for control of industrial wastes and other high mineral water,

the Hyperion effluent would be of better mineral quality. The Azusa mineral pickup can be used as a yardstick for minimum mineral pickup. Table 5 classifies the Azusa and Los Angeles effluents in terms of the agricultural standards. The Azusa sewage does not contain appreciable brine or industrial wastes and may be considered a representative domestic Southern California sewage effluent. Industrial and potable water quality standards, in general, are in the same approximate range as the agricultural quality standards with certain exceptions which need not be discussed in this paper.

Analyses of Surrounding Ground Water.—The Los Angeles County Flood Control District has taken samples in the neighborhood of the Azusa sewage treatment plant as well as in other surrounding areas for many years. Table 6 compiles the results of these and other analyses. It will be noted from Table 6 that there is no consistent pattern of degradation of the ground water that can be attributed to the Azusa sewage discharging into the underground aquifers. Table 2 indicates quite clearly that, contrary to obvious considerations, all the mineral constitutents present in the spread effluent do not remain in the percolated liquid. For example, the total nitrogen present in the samples collected at the 7-ft-depth collection pans at Azusa is much less than that present in the spread waste waters. Evaporation of ammonia gas, loss of nitrogen (as N) to the atmosphere, fixation of nitrogen in the organic matter in the surface soil—are factors causing this nitrogen removal. Similarly, base exchange relationships between the percolating effluent and the soil, flocculation phenomenon, and other physical-chemical-biological factors may influence certain ions.

Water percolating through the soil into the underground aquifer, of course, will dissolve considerable mineral content. Hence even rain water, after recharging to the underground, contains the various categories of anions and cations. With this thought in mind, the feasibility of direct re-utilization of properly controlled and treated waste waters for cropping, industry, or recharge gains new validity.

Corrections for Transactions. A corrected form of Table 2 contains the summary of the mineral analyses for the Azusa tests.

TABLE 2.—MINERAL ANALYSES IN PPM—AZUSA SPREADING TEST

Sample	Total Solids	Component											pH
		Sodium (Na^+)	Potassium (K^+)	Calcium (Ca^{++})	Magnesium (Mg^{++})	Sulfate ($SO_4^{=}+$)	Bicarbonate (HCO_3^-)	Chloride (Cl^-)	Nitrate (NO_3^-)	Ammonia (NH_3)	Nitrogen Organic (N)	Boron (B)	
(*a*) AZUSA PLANT, MAY 19, 1949													
Raw Influent	550	61.0	12.4	44.4	14.4	19.8	369	61.5	0.1	34.6	14.5	0.5	7.1
Primary Effluent	554	64.0	13.6	47.2	15.0	3.3	370	70.1	0.08	33	12.7	<0.1	7.1
Trickling Filter Effluent	506	64.9	15.6	43.5	12.6	42.8	182	68.6	1.4	5.4	7.8	0.2	7.0
Influent Percolation Basin	494	64.0	15.6	49.3	12.0	47.3	182	67.0	2.0	4.6	6.4	0.2	7.0
Far End of Percolation Basin	430	58.0	20.8	32.0	18.3	42.4	176	67.6	1.6	5.6	6.3	0.1	7.0
(*b*) AZUSA WATER SYSTEM, MAY 17, 1949													
Azusa Top Water	381	9.6	3.1	54.4	14.4	27.2	206	11.2	0.2	...	...	0.1	7.4
Well No. 1	391	9.3	3.1	52.0	14.6	28.0	206	9.7	0.56	...	...	0.1	7.3
Well No. 2	224	...	...	...	...	...	205	7.6	...	...	...	...	7.3
Well No. 3	200	9.2	4.5	48.0	13.2	22.6	193	7.6	1.2	...	...	0.2	7.3
Well No. 4	400	19.6	1.6	76.8	16.4	37.4	283	21.3	1.6	...	...	0.1	7.3
(*c*) AZUSA PLANT, JUNE 17, 1949													
Raw Influent	720	82.1	12.4	...	...	...	383	103.7	0.13	29	7.7	1.3	...
Primary Influent	532	61.0	12.4	...	...	...	390	51.8	0.8	23.4	9.1	1.6	...
Trickling Filter Effluent	512	62.6	13.1	...	...	...	200	45.8	0.4	3.2	3.8	<0.1	...
Influent Percolation Basin	480	64.8	12.8	...	...	...	193	45.8	0.4	5.6	3.9	1.7	...
Far End of Percolation Basin	488	64.0	13.3	...	...	...	176	50.8	0.28	0	7.3	1.2	...
(*d*) AZUSA PLANT, JUNE 20, 1949													
Influent Percolation Basin	606	...	...	...	...	...	220	62.8	0.8	9.4	8.0	...	...
Far End of Percolation Basin	480	...	...	...	...	...	194	41.6	1.0	3.9	5.2	...	...
Percolation Fluid 2½-ft Depth	400	53	12.2	51.4	15.5	56.4	205	40.5	1.6	0.3	2.4	0.5	...
Percolation Fluid 7-ft Depth	420	53	12.5	51.2	15.5	48.1	228	43.7	0.4	0.4	2.4	0.3	...
(*e*) METROPOLITAN WATER DISTRICT 1947 TO 1948													
...	727	190	3	30	14	319	99	98	0.01	...	...	0.14	...